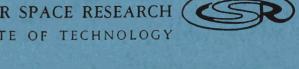FOURTEENTH SEMIANNUAL PROGRESS REPORT

July 1970

NASA Grant NGL 22-009-019

CSR PR-0471-4

CENTER FOR SPACE RESEARCH

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

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MASSACHUSETTS INSTITUTE OF TECHNOLOGY
Center for Space Research

FOURTEENTH SEMIANNUAL PROGRESS REPORT

For the Period

December 1, 1969 to May 31, 1970

on

NASA Grant NGL 22-009-019

To The

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Office of University Affairs

FOREWORD

The research which has been carried out at the M.I.T.
Center for Space Research under NASA grant NGL 22-009-
019 for the period December 1, 1969 through May 31,
1970, is summarized in the following report.

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PHYSICAL SCIENCES AND ENGINEERING

STAR EVOLUTION STUDIES

Investigators: I. Iben, Jr., Z. Abraham, J. P. Huchra, R. T. Rood, W. D. Watson

Project No.:   DSR 70469

Abraham has continued to explore the effect on solar neutrino fluxes of varying a number of different input parameters. Earlier conclusions seem to hold and a significant discrepancy with the Davis experiment remains. Of particular interest is a conclusion concerning Kucharov's suggestion that, if the sun is now burning primarily via the $He^3 + He^3 \rightarrow He^4 + 2p$ reaction, Davis should get a null result. We have shown that Kucharov's suggestion implies that at least 20 percent of the sun's initial mass was in the form of deuterium or He^3, a situation contrary to that implied by the abundances of He^3 and He^4 in Gas Range meteorites.

Rood has continued to construct horizontal branch and asymptotic branch models. Of particular significance is the discovery of a "suprahorizontal branch" whose properties (on comparison between theory and observation) bolster conclusions concerning a significant mass spread among horizontal branch stars.

Watson has discovered a mechanism for accounting for the peculiar abundances in Am stars. The mechanism involves competition between selective radiation pressure-induced diffusion and gravity diffusion at the base of the thin convective layer near the photosphere.

Iben has written a program to examine pulsation properties of RR Lyrae Stars and, in conjunction with J. Huchra, is discovering many marvelous things.

Publications

1. Rood, R. T. "Metal Poor Stars II. Initial Horizontal Branch Models," Ap. J. (July 1970).

2. Iben, Jr. I. and R. T. Rood: "Metal Poor Stars III. On the Evolution of Horizontal Branch Stars," Ap. J. (August 1970).

3. Strom, S. E., K. E. Strom, R. T. Rood and I. Iben, Jr.: "On the Evolutionary Status of Stars Above the Horizontal Branch," <u>Astronomy</u> <u>and</u> <u>Astrophysics</u> (September 1970).

4. Iben, I., Jr.: "Globular Cluster Stars," <u>Scient</u>. <u>Am</u>. (July 1970).

Submitted for Publication

5. Watson, W. D.: "The Solar Core Opacity," <u>Ap</u>. <u>J</u>. (July 1970).

6. Simoda, M. and I. Iben, Jr.: "Time Constant Loci and Luminosity Functions for Metal-Deficient Clusters," <u>Ap</u>. <u>J</u>. <u>Suppl</u>. <u>183</u> (August 1970).

7. Watson, W. D.: "Element Diffusion and Abundance Anomalies in Metallic-A Stars," submitted to <u>Ap</u>. <u>J</u>. , June 1970.

8. Rood, R. T.: "Models for Partially Mixed Stars," submitted to <u>Ap</u>. <u>J</u>., June 1970.

MARS SPECTRAL REFLECTIVITY

Investigator: T. B. McCord

Project No.:   DSR 70470

Spectral reflectivity observations by the principal investigator
(McCord, 1969a) of the surface of Mars during the 1967 opposition,
when combined with data already in the literature, revealed
distinctive structure in the spectral reflectivity curve 0.30
to 1.20 microns for both bright and dark martian regions (McCord
and Adams, 1969). In addition, the spectral curve seems to
change with martian season. Laboratory observations by Adams
and Filice (1967), Adams (1968, 1969), and others of the spectral
reflectivity of common terrestrial minerals and rocks indicate
that the planetary spectral reflectivity curve can be inter-
preted in terms of the planetary surface mineralogy and geology
(see, for example, Adams and McCord, 1969; Adams, 1968).

The objectives of the Mars spectral reflectivity study described
here are to observe various areas of the surface of Mars at
several different times during the 1969 opposition and to inter-
pret these observations in terms of surface mineralogy and sur-
face processes. The spectral region covered has been expanded
from that of the original observational work (McCord, 1969) to
the entire region in which reflected solar radiation is important,
0.30 to 2.50µ. Measurements were made at three different times
during the Mars opposition with the hope of obtaining the maximum
martian seasonal change in the reflecting properties. These new
spectral reflectivity curves were analyzed for spectral structure
differences for the martian regions and for changes with martian
season. Also, the new data were compared with previous data
(McCord and Adams, 1969) to determine changes in the martian
reflectivity over periods of years. In addition, there is some
hope that transient phenomena, such as clouds and frost, were
observed.

The basic approach was to use a special double-beam photometer
designed by the author (McCord, 1968) to make comparative colori-
metric observations through 52 narrow-band interference filters.
The instrument allows the elimination from the data of the effects
of terrestrial atmosphere transparency variation. Thus, very
precise measurements, on the order of 0.1 percent, are possible.

Two basic observational requirements are (1) very great image stability (seeing), because the surface features of Mars to be observed are very small in angular size, and (2) a telescope located at a southerly latitude, because Mars appears at about -25° declination during the 1969 opposition. Therefore, the 60-inch telescope of the Cerro Tololo Inter-American Observatory, Chile, was used. Three 12-day observational periods were planned: one in March, one in late May and early June, and one in September.

The study was begun during the last half of 1968 and the first half of 1969. Equipment was designed and obtained, and observing time on the Cerro Tololo 60-inch telescope was awarded. Also, a study of existing data was completed and published (McCord and Adams, 1969; Adams and McCord, 1969).

During the first observing period, March 5 to March 16, Mars was observed on about eight nights. The equipment functioned perfectly and most of the observing program was accomplished. The second observing period was completed successfully. Again all went well. However, during the last observing run bad weather was encountered and only a few measurements could be made.

During the first period of the project the large quantity of data was reduced and analyzed. Preliminary results were presented at several scientific meetings (McCord and Westphal, 1970a, b). The results are now being written up in several papers to be submitted this summer to scientific journals for publication.

In the observational part of this program the principal investigator is working in cooperation with Mr. James Westphal of the California Institute of Technology. Dr. John Adams of the Caribbean Research Institute is a participant for final interpretation of the data.

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6. McCord, T. B.: "Comparison of the Reflectivity and Color of Bright and Dark Regions on the Surface of Mars," Ap. J. 79 (1969).*

7. McCord, T. B. and J. B. Adams: "Spectral Reflectivity of Mars," Science 163, 1058 (1969).*

8. McCord, T. B. and J. A. Westphal: "Spectral Reflectivity of the Martian Surface," presented at meeting of American Geophysical Union, April 20-24, 1970, Washington, D. C.*

9. McCord, T. B. and J. A. Westphal: "A Colorimetric Study of Mars during the 1969 Apparation," presented at the American Astronomical Society, January 19-21, 1970, San Francisco.*

TOPICS IN THEORETICAL ASTROPHYSICS AND COSMOLOGY

Investigators: P. Morrison, L. Sartori, F. M. Flasar,
                 S. O'Dell, M. Kafatos

Project No.:   DSR 70474

I.   Spinars

Work is in progress by Flasar and Morrison (with A. Cavaliere)
on a more complete account of spinars, both in relation to M87
with a more general outline of their evolution. This paper
was delivered orally in part at the Vatican Study Week on Active
Galactic Nuclei, April 1970 in Rome.

II.   Sychrotron Emission and Cyclotron Emission

L. Sartori and S. O'Dell have studied carefully the limits on
the synchrotron process for high magnetic fields and for high
particle energies. A novel result appears to be that the radio-
silent objects, probably spinars, found in QSOs and in some
active galactic nuclei, have low frequency emission cutoff well
above the rf region because insufficiently high magnetic fields
cyclotron emission, rather than synchrotron self-absorption,
limits the spectrum at the low frequency end. A paper is in
progress.

III.   Emission Regions around Supernovae

M. Kafatos has shown that the large suddenly-produced photo-
ionized regions of great volume but very low emission measure
which are expected around supernovae on the basis of the S
fluoresence theory of the light curve might be detectable both
in the uv and the ir. He is suggesting experiments to check
the prediction. A paper is in its early stages.

IV.   Gamma Rays from the Galactic Nucleus

K. Brecher included this problem in his Ph.D. thesis (September
1969). He is publishing from UCSD (La Jolla) a paper with a full
account of his work; an abstract has already appeared.

STELLAR THEORY

Investigators: W. K. Rose, R. L. Smith

Project No.:   DSR 70475

I.   Novae and Planetary Nebulae

A hydrodynamic code that is capable of studying detailed physical
models for unstable stellar models has been successfully developed.
Unstable stellar models are being studied with the eventual hope
of obtaining a better theoretical understanding of the physical
processes associated with the nova outburst and the formation
of planetary nebulae.

II.   Neutron Stars

Calculations that show how nuclear matter affects physically
plausible models for neutron stars have been completed, and a
paper has been published in collaboration with C. G. Wang and
S. L. Schlenker.

III.   Protostars

A theoretical investigation of protostars has recently been
initiated.

IV.   The first draft of a book dealing with modern topics in
astrophysics has been completed.

Publications

1.   Rose, W. K. and R. L. Smith: "Final Evolution of a Low
      Mass Star I," Ap. J. 159, 903 (1970).

2.   Wang, C. G., W. K. Rose and S. L. Schlenker: "Models for
      Neutron-Core Stars Based on Realistic Nuclear-Matter Cal-
      culations," Ap. J. 160, L17 (1970).

3.   Harper, R. and W. K. Rose: "Nonradial Oscillations of
      White Dwarfs, Hot White Dwarfs and 10 M☉ Models," Ap. J.
      (in press).

INTERFEROMETRIC SPECTROSCOPY OF PLANETARY ATMOSPHERE

Investigators: T. B. McCord, C. Pilcher

Project No.:   DSR 70476

The program to develop and use a Fourier interferometer spec-
trometer to make high spectral and spatial resolution observa-
tions of Jupiter and Saturn was just begun this past year.
The interferometer is on hand and operating, and the fore-
optics and detector optics are well along in construction,
as is the data system. We expect a working instrument this
summer. We are scheduling telescope time both at the Mt.
Palomar 200-inch and the Cerro Tololo 60-inch to use the
instrument on Jupiter. Mr. Carl Pilcher is doing a Ph.D. thesis
using this device. He has been instructed in the design and
construction of the devices and he should acquire all of the
data pertinent to his thesis during the next year.

PROBLEMS IN ASTROPHYSICS

Investigators: C. C. Lin, S. Feldman, C. Hunter, W. W. Shane,
                 A. Toomre

Project No.:   DSR 70477

Lin devoted much of his time to the preparation of an invited
discourse for delivery at the General Assembly of the Inter-
national Astronomical Union. This is a comprehensive review
paper of the progress in the theory of spiral structure of
galaxies during the past decade, including, in particular, our
work done here supported by the NASA grant. A copy of the paper
has been submitted separately to NASA to serve as a final report
of our work performed under NASA sponsorship.

During the preparation of this report, we are fortunate to have
Dr. W. W. Shane here from Leiden to correlate his observational
data with our theory. This turns out to be very successful as
a difficulty of long standing in the Scutum area (near galactic
longitude $\ell^{II} = 20° - 25°$) can now be resolved. The observed
features can be integrated with features identified with the
"3-kpc arm."

Toomre has now worked out patterns of interacting galaxies. The
intergalactic bridge can be described in evolutionary detail*.
Work was done with large computers with time allotted by the
NASA Space Institute in New York City. A movie is available for
showing the results obtained.

Hunter studied the rotation and angular momentum of galaxies
and the disk-like Riemann Ellipsoids. The latter gave some
indication of the overturning of gas observed in the Milky Way.

Lin and Feldman have developed a theory to account for the dis-
tribution of ionized hydrogen in the Milky Way system. As is
well known, their detailed distribution (i.e., motions) agrees
with neutral hydrogen, but the abundance distribution of the
two components differs greatly. This point has now been explained
in quantitative detail*.

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*   Reported in the invited discourse mentioned above.

Publication

1.   Hunter, C.:   "Stellar Hydrodynamic Equations for a Thin Disk Galaxy," Studies in Applied Math. 49, 59-68 (1970).

To Be Published

2.   Hunter, C.:   "Large-Scale Oscillations of Galaxies."

3.   Hunter, C.:   "The Disk-Like Riemann Ellipsoids."

4.   Hunter, C.:   "The Rotation and Angular Momentum of Galaxies."

5.   Lin, C. C.:   "Interpretation of Large-Scale Spiral Structure."

6.   Lin, C. C.:   "Theory of Spiral Structure," (invited discourse, August 1970).

7.   Toomre, A.:   "Forced Oscillations and Spiral Structure."

8.   Yuan, C.:   "Theoretical 21 cm Profiles."

KINETIC THEORY OF PLASMAS

Investigators: J. E. McCune, C. K. W. Tam, J. D. Callen,
                 T. R. Young

Project No.:   DSR 70478

I.   Electrostatic Instabilities in the Magnetosphere (McCune, Callen, Young)

Recent definite observations of electrostatic wave emissions
in the earth's magnetosphere[1] have provided fresh impetus for
our study of electrostatic instabilities in that environment.
Observations indicate very strong electrostatic emissions at
frequencies near $(n + 1/2)\omega_{ce}$ and also at $\omega \gg \omega_{ce}$, and further
indicate their location to be predominantly at low latitudes
just outside the plasmapause $4 < L < 0$ on the earth's dawn side.
We have developed a model of the electron distribution function
which can explain instabilities of this sort and are currently
starting numerical calculations to determine the unstable wave
properties in the interesting parameter regimes. Our model of
the electron distribution is consistent with other, more direct
--but limited--observations made in this region and may provide
more detail concerning the anisotropy of the electrons. If the
model is successful, calculation of the wave properties, particu-
larly localization at low latitudes, can then be refined using
the integral equation developed earlier under this program.

II.   Nonlinear Dispersion of Plasma Waves (Tam)

The nonlinear dispersion theory reported earlier has been success-
ful in predicting the field-aligned propagation property of
whistlers and the nonlinear stability boundary of cold plasma
waves. However, the theory is restricted to the zero side band
wave limit. In its present form it, therefore, cannot predict
the unstable side band spectra and the growth rates of the unstable
side band waves. An extension to the existing theory has now
been found and an investigation is underway to establish the
spatial growth rates of the unstable whistler waves. Comparisons
with earth-based whistler decay rate data will be made as work
progresses.

III. The Interaction of Wave Turbulence and the Magnetopause
(Tam)

A theoretical analysis on the interaction of wave turbulence in the magnetosheath and the magnetopause has been completed. This investigation was motivated by the suggestion made by W. I. Axford[2] that this interaction will give rise to a sufficiently strong turbulent shear stress at the magnetospheric boundary to generate large scale internal convection currents inside the magnetosphere. An MHD model is used in the present work which is believed to be adequate for the present purpose. It is found that the turbulent shear stress depends linearly on the turbulent magnetic field energy and the kinetic energy of plasma fluctuations. On using data of the magnetopause obtained by Pioneer 6 and turbulent wave energy obtained by Pioneer 5, the present calculation gives a turbulent shear stress of the order of 10^{-19} dyne/cm^2. This is several orders of magnitude smaller than Axford's original estimate. It is, therefore, believed that turbulent shear stress is perhaps not the mechanism that is responsible for the large scale internal convection currents inside the magnetosphere. This work has been submitted for publication in the Journal of Plasma Physics.

References

1. Kennel, et al.: TRW Report 05402-6017-RO-00, January 1970.

2. Axford, W. I.: Plan. Sci. 12, 45 (1964).

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3. Tam, C. K. W.: "Amplitude Dispersion and Nonlinear Instability of Whistlers," Physics of Fluids 12, 1028 (1969).

4. Tam, C. K. W.: "Nonlinear Dispersion of Cold Plasma Waves," J. Plasma Physics 4, 109 (1970).

5. Tam, C. K. W.: "The Interaction of Homogeneous Wave Turbulence and a Magnetohydrodynamic Tangential Discontinuity," submitted to J. Plasma Physics (1970).

AÜGER ELECTRON SPECTROSCOPY

Investigators: R. E. Ogilvie, J. Adario

Project No.:   DSR 70479

Introduction

It has been well established that, when an x-ray or an electron beam irradiates the surface of a specimen, the atoms of the specimen will be placed in an excited state. The return to the ground state can take place by one of two processes: by the emission of a characteristic x-ray or an Aüger electron. The x-rays can escape from a depth of several microns whereas the electrons, which have a much shorter range, come from a depth of only a few atom layers. The method is thus most useful for characterizing surfaces and their constituents.

The chemistry can be determined from the analysis of these electrons because they too have a characteristic energy that is determined by the particular atomic number of the element. Weber and Peria[1] have shown that a few percent of a monolayer coverage of alkali atoms (K or C_s) is detectable on a clean silicon surface. This implies a surface density of about 10^{14} atoms/cm^2. Where depth effects do not enter into consideration, the amplitude of the Aüger line is proportional to the quantity of material present on the surface.

The most obvious use of secondary electron emission spectroscopy is the qualitative identification of surface contaminants. Thus residues from organic solvents, plating baths and other fabrication processes have been found on all types of surfaces.

Previous Work in the Field

The monumental work of Siegbahn[2] and co-workers on Aüger, and in photo-electron spectroscopy particularly, is well recognized. Siegbahn's work employed characteristic x-ray excitation. However, in this particular program we shall be using both x-ray excitation and electron excitation.

Harris[3] using electron excitation proved that by electronic differentation of the electron energy distribution the sensitivity could be greatly enhanced. Weber and Peria have shown that a standard three-grid low energy electron diffraction system may be employed for measurement of the derivative of the energy distribution function. Palmberg and Rhodin[4] have also used a three-grid LEED system. The results of this latter work showed that the mean escape depth for Auger electrons in silver varies between 4 and 8 Å for energies of 72 and 362 eV, respectively.

The Electron Energy Analyzer

For many years the concentric spherical deflection analyzer as described by Purcell[5] has been considered the best electrostatic analyzer known, the reduced dispersion being larger than either that of the concentric cylindrical deflection device or the parallel plate mirror analyzer. Furthermore, the spherical deflection system provides two-dimensional focusing as an additional advantage in devices using axially symmetric beams. Recently, Zashkvara[6] et al. have shown the cylindrical mirror analyzer used by Blauth[7] to have the unsuspected property that second order focusing occurs at an entrance angle of 42.3° and $E/eV = 1.3/\ln r_2/r_1$ where V is the potential difference between the two concentric cylinders of radius r_1 and r_2 and E_0 is the energy of the electron. It has been shown by Häfner[8] et al. that the design by Zashkvara has an improvement in the resolving power over the spherical analyzer. This has been demonstrated by Ogilvie[9] in a system designed to fit into the scanning electron microscope. A similar system was built by Sar-el[10] who independently found the unsuspected focusing properties of the concentric cylinders.

We have finished building a much larger analyzer than the one we made for the SEM. This new system has a special x-ray source that we have designed in our laboratory. The power supply arrived around the first of July but has not as yet been connected to the system. However, we hope to have it in operation before the first of September.

The Vacuum System

The initial work will be done in a conventional vacuum bell-jar system. At present it is possible to obtain a vacuum of 10^{-6} torr. However, this will not be good enough for the final

operating system. The vacuum must be 10^{-9} torr or better when using electron excitation. The reason for this is that the electron beam decomposes the hydrocarbons present on the surface of the specimen. In a few seconds only the carbon Auger can be observed. However, with the poor vacuum (10^{-6}) we shall be able to test the electron optics and resolution of the system. When we have achieved the performance that we expect, we shall then set up a high vacuum system.

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2. Siegbahn, K. et al.: Technical Report AFML-TR-68-189 (1968).

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4. Palmberg, P. W. and T. N. Rhodin: J. Appl. Phys. 39, 2425 (1968).

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ANALYSIS OF REACTOR PHYSICS AND HEAT TRANSFER

IN NUCLEAR ROCKET REACTORS

Investigators: E. A. Mason, K. F. Hansen, T. R. Simpson,
P. F. Deaton

Project No.: DSR 70480

An investigation of the heat transfer optimization of nuclear
rocket reactors which uses the method of maximizing the axial
power profile such that all parts of the reactor core operate
at steady state at one of three thermal limitations: (1) maxi-
mum thermal stress, (2) maximum channel wall temperature and
(3) maximum fuel centerline temperature, has shown that the
details of such optimum power profiles are strongly dependent
upon the exact mathematical form of the turbulent hydrogen heat
transfer correlation, especially in the reactor core inlet
region. In particular, many available correlations[1] consistently
predict an unusual wall temperature behavior which would seri-
ously limit steady state operation, while one recent correlation[2]
does not predict such behavior but this correlation has a larger
correlational error than the others. Since there is some exper-
imental justification[3] for the anomalous wall temperature behavior
with hydrogen as the coolant, the suitability of the very high
performance steady state optimum power profiles is unresolved.
However, the overall physical dimensions and specific impulse
of such optimized nuclear reactor cores are relatively insensi-
tive to the heat transfer correlation used in calculating the
optimum internal power shape. Using a channel hydraulic diameter
of 0.1 inch and a total thrust of 250,000 lbf, optimized reactor
cores were calculated to be roughly 2.1 feet in length, 0.9 foot
in radius, and capable of 900 seconds in ideal vacuum specific
impulse. At lower flow rates a gain in I_{sp} to approximately
950 seconds would require the core radius to increase to 2.74
feet and give a more "pancake" configuration.

An investigation of the neutron physics of such compact reactor
cores fueled by uranium-235 dispersed in graphite with a thick
beryllium reflector has shown that (1) these reactor cores have
fast neutron spectra dominated by fast neutron leakage, (2)
reactivity insertion by the steadystate non-uniform core hydrogen
distribution is worth roughly 2.50 $ - 3.20 $ of reactivity
(1 $ = 0.0064 $\Delta k/k$), with the smaller reactivities being for

the smaller reactor cores, (3) reactivity insertion by hydrogen
in the beryllium reflector is worth roughly 4.30 $ for 15 percent
reflector void fraction and roughly 7.80 $ for 30 percent reflector
void fraction, (4) temperature expansion of the core radius from
cold to hot decreases the reactivity by roughly 1 $, and (5) a
nominal 3 percent core carbon loss by hydrogen corrosion can also
decrease reactivity by roughly 1 $. Therefore, these compact,
fast reactor cores are considerably affected by the insertion of
hydrogen into the thick beryllium reflector, with the reflector
hydrogen reactivity being considerably greater than the steady
state core hydrogen insertion. A calibration of reflector
hydrogen reactivity worth has shown that the reactivity is nearly
linear with hydrogen concentration.

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    Rocket Nozzles," AIAA-68-608.

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    Surface Temperatures in Hydrogen-Cooled Nuclear Rocket
    Reactor at High Surface-to-Bulk-Temperature Ratios,"
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COMBINED RADIATION AND CONDUCTION HEAT TRANSFER

Investigators: L. R. Glicksman, P. A. Sykes

Project No.:   DSR 70481

The purpose of this project is to investigate experimentally
heat transfer by combined radiation, conduction and/or convec-
tion in an absorbing-emitting medium and to check the validity
of simplified analytical models. Molten glass was chosen as
the modeling fluid because its physical properties are rela-
tively easy to model.

An approximate technique has been developed to predict the
temperature profile and heat flux in a non-gray medium between
gray walls. The technique can handle a medium with optically
thin and thick zones plus an intermediate gray zone. Addi-
tional approximations for the optically thick case have been
developed and compared closely with numerical solutions. For
non-gray media the Rosseland approximations with jump boundary
conditions is shown to give poor results for the wall slip.
When a band of intermediate thickness is present, the Rosseland
results are not valid.

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      Transfer in a Non-Gray Medium," S. M. Thesis (1970).

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      Medium," to be presented at special session on Heat Transfer
      in Semitransparent Materials, ASME Annual Meeting, December
      1970.

3.   Jeryan, R., N. D. Eryou and L. R. Glicksman: "An Optical
      Method of Measuring Temperature in High Temperature Semi-
      Transparent Media," to be presented at the Annual Meeting
      of the Glass Division, American Ceramic Society, October
      1970.

MECHANISM OF TRANSIENT NATURAL CONVECTION IN

ROCKET PROPELLENT TANKS

Investigators: R. C. Reid, L. B. Evans, J. J. Noble, P. C. Pan

Project No.:   DSR 70482

The purpose of this work is to gain an improved understanding
of the fundamental mechanisms which govern the reduction of
thermal stratification of fluids in large enclosures. The
research has focussed, in particular, upon the effect of wall
thermal boundary conditions on the stability of the resultant
natural convection.

As part of his doctoral thesis investigation, Mr. Peter C. Pan
has completed the formulation of such a stability analysis and
written a digital computer program for the IBM 360 which obtains
solutions to the disturbance differential equations for parallel
or nearly parallel laminar natural convective flows. Essentially,
the method consists of treating the boundary value problem as
an initial value problem and integrating the disturbance differ-
ential equations forward and backward by the 13th order Runge-
Kutta-Fehlberg formula. The method has appeared to be rapid
and highly accurate, and the program is sufficiently general
to allow a variety of profiles and boundary conditions to be
studied.

The computer program was first used to study the stability of
the natural convection of a viscous fluid within a vertical
slot having isothermal sidewalls at different temperatures (in
the conduction regime). The objective here was to verify that
the program functioned properly, since the stability character-
istics for this phenomenon had been experimentally established
and a number of approximate analytical solutions also existed.
Numerical solutions of neutral stability curves, critical Grashof
numbers and critical wave numbers were computed for 30 different
Prandtl numbers ranging from 10^{-4} to 10^3, and separately for
Prandtl numbers equal to zero. In addition, the streamlines
and isotherms of both the disturbance and total disturbed flow
were also computed for each Prandtl number and its corresponding
critical states. All these theoretical predictions were found

satisfactorily in agreement with the available experimental observations reported in the literature. Both the critical Grashof numbers and wave numbers were found to be weak functions of the Prandtl numbers. The weakness of the Prandtl number dependence suggested that the buoyancy force plays a small role in the destabilization of the natural convection in the conduction regime and the instability of such a flow is essentially mechanically driven. This interpretation was further substantiated when the physical mechanism of the instability of this flow was considered from an energy conversion relationship between the disturbance and the basic laminar natural convection (velocity and temperature) fields.

The main objective of this theoretical investigation is to understand the effect of wall thermal boundary conditions on the stability of the external free convection boundary layers since, for this case, the experimental data are very limited and quantitative analytical results are lacking. The stability analysis for these external free convection boundary layers are presently being performed, using the program developed in the study of the stability for the conduction regime.

Publication

1. Matulevicius, E. S.: "Thermal Stratification in Enclosed Fluids Due to Natural Convection," Sc. D. Thesis (1970).

LABORATORY FOR SPACE EXPERIMENTS

Investigators: R. H. Baker, L. H. Bannister, J. H. Binsack,
H. V. Bradt, H. S. Bridge, R. J. Butler,
G. W. Clark, J. V. Harrington, W. H. G. Lewin,
R. W. Rasche, H. W. Schnopper, I. I. Shapiro,
G. Simmons

Project Nos.: DSR 70483 and 70484

This laboratory, as an integral part of the Center for Space Research, draws its principal support from program funds as indicated in the following status report. In addition, some support is provided from NGL 22-009-019 funding for exploratory research and special projects of general interest to the space program. A number of these projects were started initially under NsG-496 funding and have subsequently found direct support from program funds in the manner indicated.

X-ray Sounding Rocket (NSR 22-009-129)

The data from flight 4.279, the first rotating modulation collimator experiment to be performed from a sounding rocket, have yielded the precise location of Sagittarius x-ray sources GX3+1, GX5+1, GX9+1 and GX17+2. The celestial positions of the above x-ray sources were located with the high precision of about one to two arc minutes. The data and results obtained from flight 4.279 will be published in an upcoming issue of the Astrophysical Journal.

On May 7, 1970, Aerobee rocket 13.06, a 170 rocket, was successfully launched and observed the x-ray flux from the galaxy M-87. The payload performed satisfactorily for the second time and was recovered in operating condition. The data from this flight are now being analyzed.

A prototype thin window proportional counter sensitive to x-rays in the 44 Å region is now being developed. This experiment will incorporate a gas flow system to maintain a constant pressure in the counter to achieve a constant gain system. This low energy experiment is being designed to fly on a rocket along with the

previously flown rotating modulation collimator. This flight
is being prepared for launch in March 1971.

Multicolor X-ray Survey Experiment (OSO-H) (NAS 5-11082)

Work is continuing on the construction and test of a comprehen-
sive x-ray survey experiment to be flown on the Orbiting Solar
Observatory-H.

The construction and test of the prototype unit is nearing com-
pletion. The unit will be bench-tested during August. Construc-
tion of the flight unit is in progress. Delivery of the flight
unit is currently scheduled for October.

Small Astronomy Satellite-C (NAS 5-11275)

A new program to design, develop, launch and operate an extensive
x-ray survey experiment using the Small Astronomy Satellite-C
has been initiated within the Center. A preliminary study
program is now being implemented.

The scientific payload is composed of four separate complementing
experiments. Professor Clark, who is the principal investigator
for the entire experiment, is carrying out a low energy observa-
tion of the diffuse x-ray background to determine galactic x-ray
absorption profiles. Professor Bradt, co-investigator, is
responsible for a galactic x-ray source survey experiment. This
experiment utilizes technology developed on the x-ray sounding
rocket program and has as its primary objective the precise
location of discrete x-ray sources. Professor Lewin, co-inves-
tigator, is responsible for an experiment to monitor the x-ray
source, Sco X-1. The experiment will permit the study of time
variations on the order of milliseconds throughout a wide energy
range over a prolonged period of time on this extremely inter-
esting source. Professor Schnopper, co-investigator, is in
charge of an extra-galactic x-ray survey experiment which utilizes
the "rotating modulation collimator" technique so successfully
used on sounding rocket 4.279 (see x-ray sounding rocket program).

Current efforts are primarily directed towards the configuration
of the scientific aspects of the experiment. An increase in the
scope of the study is now being negotiated.

IMP H and J Plasma Experiment (NAS 5-11062)

The engineering model of the system has been completed and tested using standard laboratory equipment. A more comprehensive test of the experiment will be conducted using a plasma simulator for stimulating the experiment and employing a small process control computer (HP 2115A) to read, analyze, format and print out the experiment telemetry output. The computer has been interfaced with the engineering model and the programming is being debugged. The plasma simulator is being fabricated and will be interfaced with the experiment shortly.

Portions of the flight unit have been designed and fabricated (the sensor and the measurement chain) and are being electrically tested.

Mechanical layout of the balance of the circuits is in process. Approximately half of this layout work is being done using conventional methods. The other half of the layout work (principally the logic circuits) is being accomplished by employing a computer for design of the printed circuit boards. The first board will be available from this technique about July 17, 1970. The elapsed time for this first board will be about three weeks. The balance of the board designs will be done at the rate of two per week thereafter. This technique appears to be a great time-saver and probably can reduce the overall system design cost.

The subcontractor's modulator breadboard has been completed, and the vendor is proceeding on the flight unit. Delivery is late and critical.

The present schedule requires initial delivery of the first flight unit in December 1970. The launch is still scheduled for February 1972.

Rotating-Beam Antenna

As part of a system for navigation and direction finding on the lunar surface, it is desirable to create an antenna which can produce a far-field radiation pattern of which only the direction of the peak can be changed by electronic means. One candidate for such an antenna is a rotating Hertzian dipole, which is created by a suitable amplitude modulation of the currents in two perpendicular Hertzian dipoles.

Neglecting any effects of a material medium, such an antenna has an aximuthal radiation pattern with peaks normal to the approximate instaneous dipole orientation axis. This pattern is ideally a dipole pattern with polarization in the azimuthal plane. More generally, it is possible to produce a rotating figure-eight or dumbbell pattern with a minimum azimuthal amplitude which never goes to zero, by means of an additional rf phase modulation or relative phase retardation between the two dipole currents.

The advantage of a rotatable figure-eight pattern lies in the possibility of using a phase-locked oscillator in a receiver, which will theoretically always receive a minimum signal strength. The disadvantage of the figure-eight antenna is primarily in the additional complexity in the hardware necessary to generate the simultaneous phase shift and power split between the two dipole currents.

The work is continuing and will be reported on in greater depth in subsequent periods.

Lunar Surface Radio Beacons

As previously reported, X band radio beacons emplaced on the lunar surface would make possible an international cooperative program of very long baseline radio interferometry observations having significance in many scientific areas. Using the three receiving systems now employed by M.I.T. for interferometric observations of celestial noise sources, the lunar orbit and librations could be determined precisely enough to permit a measure of the nodal precession predicted by general relativity and to permit observation of the lunar analogue of the anomalous Chandler wobble.

Conversely, once the angular location of an emplaced radio beacon has been determined precisely, the beacon could be used as a reference for a determination of the relative location of other receiving points on earth. This series of observations would permit a direct measure of intercontinental drift and would permit a precise measure of the relative locations of the NASA deep space tracking network stations.

During this reporting period, a conceptual design has been completed for an improved radio beacon that would permit these observations to be made with any receiving dish having a diameter greater than about 15 feet: this is adequate to allow participation by virtually all current NASA tracking stations. Based

on the improved beacon design, it is computed that the uncertainty in the relative locations of these stations could be reduced from the present tens of meters to a few centimeters.

Power consumption of the improved beacon has been reduced significantly from 10 watts to 5 watts. Weight has been reduced slightly from 7 pounds to 6 pounds. Volume has been reduced very slightly from 600 cubic inches to 570 cubic inches.

Improved performance of the beacon is due primarily to an improved electrical design which permits the radiated energy to be concentrated in discrete frequency bands. These bands are chosen to optimize the interferometric delay function measurement. Further, the frequency bands are constrained so that the effective noise bandwidth of the receiving system can be reduced significantly; this does not require a change in the existing receiver hardware but can be accomplished by a change in the computer software used to effect digital filtering during the correlation procedure. The net effect of these changes is to make the effective system signal-to-noise ratio more than 30 db greater than that applicable to the broad band noise source beacon postulated previously.

COMMUNICATIONS THROUGH AN IONIZED MEDIUM

Investigators: W. B. Davenport, P. Alexander

Project No.:   DSR 76195

In previous studies of the solar corona as a transmission medium,
it has been found that the equivalent mathematical model (for
communication at 100 MHZ) can be decomposed into several simpler
types which provide an accurate description of the channel prop-
erties throughout some region of space. These properties depend
primarily on the distance of closest approach to the sun, of
the line joining the transmitter and receiver. The most severe
signal distortion occurs for paths which pass within 60 solar
radii of the sun. In this region the effects of the solar plasma
on communication schemes can be summarized by the channel scat-
tering function, which describes the average power weighting of
a continuum of delayed and Doppler shifted signals.

During the last period various aspects of the measurement of
channel scattering functions (or equivalent correlation functions)
have been investigated. The estimation of instantaneous channel
properties, such as the channel time-varying impulse response,
is not possible for systems which have an equivalent Doppler
spread delay spread product, BL, larger than unity. The average
properties are not subject to the same constraints, but it has
been found that for BL > 1, the estimate of the scattering
function is degraded considerably by bias effects. This is a
consequence of the fundamental convolutional relationships between
the signal and the channel, and results in our averaged estimate
being significantly different from the true function. Techniques
have been evaluated for eliminating this bias by suitable opera-
tions on the received signal. In addition, the Cramer Rao bound
on the variance of (unbiased) estimates has been evaluated for
joint estimates of a sampled form of the scattering function.
This establishes a reference level which can be used to evaluate
the optimality of ad hoc estimation schemes, since the Cramer
Rao bound provides us with lower bound on the variance of all
possible estimates.

For regions of operation where the spread of the channel (BL)
is much less than unity simplified estimates result by neglecting

the bias problem indicated above. The implementation of these
techniques has been considered for situations involving a small
satellite orbiting the sun and transmitting through the solar
corona to earth.

SOCIAL SCIENCES

PUBLIC MANAGEMENT OF TECHNOLOGY

Investigator: H. M. Sapolsky

Project No.:   DSR 70472

The project has broadened somewhat to include a consideration of Soviet management of technology. Despite the fact that much of United States effort in technology since World War II can be described in terms of reaction to or an anticipation of Soviet efforts, very little research has been directed toward broadening our understanding of Soviet policies in technology. During the semester an opportunity arose to bring into the project for postdoctoral study a Ph.D. chemist with a knowledge of Russian and an interest in Soviet science and technology. His work has aided the project by clarifying Soviet data relating to R&D and R&D manpower. Several separate publications are expected to result.

An analysis of U.S. policies in the management of large scale technology, however, remained the central focus of the project. A volume of essays considering the origins of large scale programs, their methods of management, government-contractor relations, the role of science advisors in determining public policy and proposals for controlling the social costs of large scale programs is in preparation. Lectures and seminar presentations testing the concepts of the essays were given at RAND, the Air Force Cambridge Laboratory, the University of Michigan and Rice University during the semester. A few short notes and reviews related to the project have already appeared.

Publications

1. Sapolsky, H. M.: "What May Happen to Research If and When Priorities Change," SPPSG Newsletter (March, 1970).

2. Sapolsky, H. M.: Review of H. Scheiber "Ohio Canal Era" in Administrative Science Quarterly (forthcoming).

3. Sapolsky, H. M.: "The Search for a Dependable and Wealthy Angel," review essay in Technology Review (July/August 1970).

FORMATION AND GROWTH OF TECHNOLOGY-BASED ENTERPRISES

Investigator: E. B. Roberts

Project No.:   DSR 76154

In attempting to bring the project toward a desired completion in the near future, several activities were aimed at finishing up earlier research. Alan Fusfeld completed the data gathering on spin-off companies from the M.I.T. Department of Chemical Engineering, leaving analysis and writeup for the next several months. Stephen Lipsey completed the work on the sample of Boston computer-oriented companies, mostly software or application firms. The number of technology-based new firms now investigated totals over 250.

Extending the earlier work by Peters[1] and by Peters and Roberts[2] in the area of idea utilization, George Morgenthaler carried out a major study in 39 organizations. His resulting thesis[3] was awarded the Brooks Prize by the M.I.T. Sloan School of Management as the outstanding S.M. thesis of the year. Morgenthaler demonstrated that entrepreneurially-oriented venture approaches for technical idea exploitation were achieving successful results and deserved further development.

Kathy Piepmeier is working with Professor Roberts to assemble the variety of research studies undertaken during the life of this project and to edit them into a cohesive presentation.

Publications

1.   Peters, D. H.: "Commercial Innovations from University Faculty: A Study of the Invention and Exploitation of Ideas," M.I.T. Working Paper No. 406-69, July 1969.

2.   Peters, D. H. and E. B. Roberts: "Unutilized Ideas in University Laboratories," _Academy of Management Journal_, June 1970.

3.   Morgenthaler, G. W.: "Decision Model and Analysis of Corporate Utilization of By-Product R&D," S. M. Thesis (1970).

STUDIES OF THE IMPACT OF THE SPACE PROGRAM ON

LOCAL, NATIONAL AND INTERNATIONAL AFFAIRS

Investigator: E. B. Skolnikoff

Project No.:   DSR 76155

While on leave during the current academic year, Professor
Skolnikoff has been devoting full time to the major portion
of this study--an analysis of the international political and
institutional implications of new technology in the near future.
The funding has come primarily from the Carnegie Endowment for
International Peace, which is also providing office space and
research assistance through its European Center in Geneva.

Work is nearing completion on a book and a series of articles
which will appear in the fall. In addition a paper has been
presented at the University of Edinburgh, which will be pub-
lished in the fall, and another will be given at the American
Political Science Association in September.

Considerable interest in the study has been generated in the
United States and among international organizations in Europe.

LIFE SCIENCES

VAPOR-LIQUID EQUILIBRIA OF VOLATILE ORGANIC SOLUTES

Investigators: P. Issenberg, C. Y. Hwang

Project No.:   DSR 70473

The purpose of this project is evaluation of the role of sorption of volatile organic compounds by solids in retention of these compounds during drying and long term storage of foods and other biological materials. The relative importance of sorption and diffusion effects depends on the nature of the materials, with resistance to diffusion accounting for retention in most of the systems investigated by other workers. In the present investigations, methods and apparatus have been developed for sorption measurements in the concentration range (parts per million) which is representative of food systems.

Studies of use of the continuous desorption method for acquiring sorption data have been continued. Attempts were made to increase flexibility of the system by packing columns with 0.5 to 20 percent sorbent, mixed with an inert solid. The objective of these studies was to minimize the effects of diffusion and non-equilibrium on measured sorption data. A column containing only PTFE, with no added sorbent, was to be used in correcting for diffusion. Several lots of chromatographic grade PTFE were evaluated, but all exhibited significant sorption of n-butanol at 23° C and below, especially in the lower range of sorbent amounts. Since no totally inert diluent solid could be found, measurements are being made in columns packed with sorbent alone. Modifications were made in the gas flow system to minimize extraneous volume and diffusion effects.

Previous studies of sorption of primary aliphatic alcohols on cellulose have been extended to other sorbents typical of the major components of dehydrated foods. Continuous desorption measurements, at concentrations ranging from 0 to 12 µg/g and at 25° to 26.5° C, have been completed for n-butanol on cellulose, potato starch, glucose and casein. Partial pressures were in the range of 0 to 17 millitorr, corresponding to a maximum activity of 2.6×10^{-3}. For each series of experiments, the influence of gas flow rate on apparent degree of sorption at constant partial pressure was determined.

All measurements were then made with a carrier gas flow rate below that at which significant deviation from equilibrium occurs. For the n-butanol-starch system, the limiting flow rate was approximately 28 ml/min, about one-half the value used in previous studies in which fixed partial pressures were employed. Use of lower flow rates also affords lower column pressure differential, resulting in reduction of pressure surges and transient effects when gas streams are switched.

A complete series of isotherms was determined for n-butanol on potato starch at temperatures of -11°, 2°, 10° and 26° C. The heat of desorption was found to be 7.63 kcal/mole at a concentration of 0.2 µg/g. These results must be confirmed by measurements at fixed partial pressures, but the values observed are consistent with those measured by other investigators for similar systems.

Publication

1. Boskovic, M. and P. Issenberg: "Model of Dehydrated Food Systems and Observations on Sorption of Some Volatile Organic Compounds on Cellulose," Proceedings, International Symposium on Surface Reactions in Freeze-Dried Products, Paris, 1969 (in press).

INFORMATION TRANSFER IN PREBIOLOGICAL ENVIRONMENTS

Investigators: A. Rich, S. Fahnestock

Project No.:   DSR 76175

An important prebiological question concerns alternative methods
of making polymers. In contemporary systems peptide bond forma-
tion in protein synthesis is catalyzed by an enzyme, peptidyl
transferase, which appears to be an integral part of the large
ribosomal subunit. In addition to the normal reaction involving
transfer of the nascent polypeptide chain from peptidyl-transfer
RNA to the alpha-amino group of aminoacyl-tRNA, this enzyme also
catalyzes peptidyl transfer reactions in which the acceptor is
the antibiotic puromycin, which resembles the aminoacyl end of
transfer RNA. Because of the similarity of the puromycin reac-
tion to the normal reaction it has proved useful in examining
the properties of peptidyl transferase as distinguished from
the specific substrate binding functions of the ribosome. In
the course of studying the structural requirements for this
reaction, we have made derivatives of puromycin in which the
α-amino group is replaced by a hydroxyl group. Study of the
activity of this modified puromycin derivative in an Escherichia
coli in vitro system has led to the discovery that the ribosome
can catalyze the attachment of an amino acid to this α-hydroxyl
group through an ester linkage almost as efficiently as it
catalyzes the formation of a peptide bond with the α-amino group.
It is of interest that most of the proteolytic enzymes which
catalyze the reverse reaction, the hydrolysis of peptide bonds,
are also esterases. This may have great bearing upon our attempts
to understand the mechanism of action of the ribosomal peptidyl
transferase and prebiotic synthesis. We have presented some of
the evidence for ester formation and make a comparison of its
efficiency relative to peptide bond formation.

Publication

1.   Fahnestock, S., H. Neumann, V. Shashoua and A. Rich:
      "Ribosome-Catalyzed Ester Formation," Biochemistry 9,
      2477 (1970).

DISTRIBUTION OF DAILY CALORIE INTAKE ON PROTEIN

AND AMINO ACID REQUIREMENTS IN ADULT MEN

Investigators: V. R. Young, M. A. Hussein, B. Torun,
N. S. Scrimshaw

Project No.: DSR 76177

Diurnal fluctuations in plasma amino acid levels have been
reported for both experimental animals and man. The mechanisms
responsible for these rhythms, the dietary factors which serve
to modify them and their physiological significance, particu-
larly in relation to the daily amino acid needs of adult man,
need further investigation.

The diurnal fluctuations of plasma-free amino acid levels were
studied under standardized dietary conditions in a total of
eleven young men. In the first experiment, six subjects were
given an otherwise complete diet supplying adequate or no
tryptophan for four to seven days, given in four equal meals
at 0800, 1200, 1700 and 2100 hours. In the second experiment
three subjects were given the adequate or tryptophan-free diet
for four and five consecutive days, respectively, as in the
first experiment, and two other subjects were given the tryp-
tophan-free diet throughout either a five- or nine-day period.
On the final day of each diet period during experiment two,
each subject received six equal meals at four-hour intervals
beginning at 0800 hours and blood samples were also taken
beginning at 0800 hours after a twelve-hour fast, at intervals
during the day.

With four meals a day, the plasma-free essential amino acids
were generally lowest at 1200 hours and began to rise at this
time with peak values being reached at 0400-0800 hours. The
tryptophan-free diet had little effect on the pattern of change
except that the amplitudes of leucine, lysine and especially
the tryptophan fluctuations were increased. The "non-essential"
amino acids showed less marked consistent fluctuations during
the day. Feeding six isocaloric, isonitrogenous meals at four-
hour intervals during the 24 hours abolished or reduced the
evening or early morning rise in plasma-essential amino acid
levels.

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We postulate that the early morning rise in venous plasma amino acid levels reflects a mobilization of amino acids from skeletal muscle and that by providing dietary carbohydrates throughout the 24-hour cycle the mobilization of amino acids from muscle is reduced, due presumably, in part, to insulin action.

These studies lead to the question as to whether, under similar dietary conditions, the needs for the dietary essential amino acids could be reduced, because the early morning increase in the plasma levels of the amino acids probably results in their subsequent oxidation, for energy purposes, in the visceral tissues. A pilot study was conducted to determine whether the feeding of three meals per day (at 0800, 1300 and 1800 hours) resulted in a higher rate of urinary nitrogen excretion when subjects are given a protein-free diet as compared with subjects given the same diet but as six isocaloric meals during the entire 24-hour day. While the results of this study suggested a more efficient utilization of endogenous protein (and, therefore, presumably a reduction in the dietary protein and amino acid needs), when the subjects consumed six meals per day, further studies involving differing levels of dietary protein will be required to establish the protein nutritional significance of the diurnal plasma amino acid fluctuations.

These studies also suggested the desirability of determining the in vivo rate of total body protein synthesis and catabolism in young adult male subjects given a diet which is distributed among different meal patterns during the day. At present we are still evaluating the proposed method, based on the frequent consumption of a glycine ^{15}N test dose during a 36 to 48 hour period. This dynamic approach to assessing protein-nutritional status in man will aid the evaluation of plasma amino acid fluctuations in relation to their nutritional significance.

We thank Professors J. Buchanan and K. Taylor (Department of Biology) for use of their mass spectrometer for the ^{15}N determinations.

Publication

1. Hussein, M. A., V. R. Young, E. Murray and N. S. Scrimshaw: "Diurnal Fluctuations of Plasma Amino Acid Levels in Adult Men. Effect of Dietary Tryptaphan Intake and Distribution of Meals," submitted to J. Nutrition.

APPENDIX

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THESES

Author	Thesis Title	Degree & Year	Department
Matulevicius, Edward S.	"Thermal Stratification in Enclosed Fluids Due to Natural Convection"	Sc.D. 1970	Chemical Engineering
Morgenthaler, George W.	"Decision Model and Analysis of Corporate Utilization of By-Product R&D"	S. M. 1970	Management
Sykes, Philip A.	"An Approximate Solution for Radiation Heat Transfer in A Non-Gray Medium"	S. M. 1970	Mechanical Engineering